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Effect of irrigation levels, crop geometry and mulching on yield, economics and water use efficiency of fennel (*Foeniculum vulgare* Mill.) grown under drip system in Western Rajasthan, India

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Abstract

A study was carried out at Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, during the *rabi* seasons of 2015–16 and 2016–17 to investigate the effects of irrigation levels, crop geometry, and mulch on yield parameters, yield, economics, and water use efficiency of fennel (*Foeniculum vulgare* Mill.). Findings showed that the irrigation level of 0.8 ETc considerably increased the yield parameters of fennel, including seed (1684 kg ha^{-1}) and stover yield (3110 kg ha^{-1}), net return (103149 ha^{-1}) and benefit: cost ratio (2.58). At 0.6 ETc, a maximum water use efficiency of 5.48 kg ha^{-1} mm^{-1} was observed. 40 cm x 60 cm paired row planting produced significantly superior yield parameters, seed yield, and water use efficiency. Results further revealed that the application of plastic mulch considerably improved yield parameters, yield, net return, and benefit: cost ratio as compared to no mulch treatment. However, test weight and harvest index were not influenced by plastic mulch. Thus, in arid and semi-arid parts of Rajasthan, integrated use of drip irrigation at 0.8 ETc and plastic mulch under paired row sowing of 40 cm x 60 cm proved more viable for ensuring higher productivity of *rabi* fennel.

Keywords: Drip irrigation, ETc, paired row, net return, productivity.

Introduction

Fennel (*Foeniculum vulgare* Mill.) is a medicinal aromatic herb with feathery leaves and golden yellow flowers and each part of it (leaves, stalks, bulbs and seeds) is edible, which belongs to family Apiaceae or Umbelliferae. Fennel is mainly cultivated for its seeds (saunf), which are used as spice in Indian culinary for flavouring soups, sauces, pickles and for seasoning breads and cakes. As a winter crop, it is mostly grown in the Indian states of Gujarat and Rajasthan, as well as in significant quantities in Uttar Pradesh, West Bengal, Karnataka, Andhra Pradesh, Punjab, and Madhya Pradesh. With an area of 79.84 thousand hectares and an annual production of 128.5 thousand tonnes, India is the world's largest producer of fennel, with a productivity of 1609 kg/ha. With an average yield of 1084 kg/ha, it covers an area of 31.62 thousand hectares in Rajasthan and produces 34.28 thousand tonnes (Spices board India, 2021-22). In locations with limited water resources for irrigation, direct seeded fennel is highly common due to its short lifetime and lower water requirement than transplanted crops. Low productivity of drilled *rabi* fennel is mainly due to poor adoption of scientific water management measures, particularly irrigation. Therefore, drip irrigation system is most suited for arid and semi-arid regions of Rajasthan, where water is scare and hence low water consuming and high value seed spices crop like fennel can be grown (Giana *et al*. 2019). Crop sowing at the ideal crop geometry is one of the crucial non-monetary inputs to increase yield. Optimum space available for individual plants at proper crop geometry might have resulted in better utilization of resources viz., space, nutrients, moisture, carbon dioxide and radiant energy to improve vegetative and reproductive growth of fennel (Tamboli *et al*., 2020). To facilitate sufficient water availability in field crops, crop geometry is modified keeping crop density unchanged. The application of plastic mulches is one of the typical methods to lower soil evaporation loss and extend the time of moisture availability to the crop. Mulching using a drip irrigation system is a successful strategy for controlling the crop-growing environment to boost output and enhance product quality (Rohitashw and Mukesh, 2020). It is crucial to preserve soil moisture and increase crop water availability given the current drought and water scarcity circumstances. Keeping this in view, the present investigation was undertaken to find out the effect of irrigation levels, crop geometry and mulching on yield attributes, yield, economics and water use efficiency of fennel (*Foeniculum vulgare* Mill.) grown under drip system.

Materials and methods

The field experiment was carried out during two consecutive *Rabi* seasons of the year 2015–16 and 2016–17 at the Swami Keshwanand Rajasthan Agricultural University, Bikaner, located in Rajasthan's hyper-arid, partially irrigated north-western plain (Zone Ic). Bikaner is located at a height of 234.70 metres above mean sea level at 28.010N latitude and 73.220E longitude. The experimental field soil had a sandy loam texture, a pH of 7.6 an electrical conductivity (EC) of 0.31 dS/m, a low level of organic carbon (0.11%), 85.31 kg/ha of available nitrogen, a medium level of phosphorus (19.8 kg/ha), and a high level of potassium (315.2 kg/ha). The experiment was laid out in split-split plot design which comprised of four irrigation levels (0.4, 0.6, 0.8 and 1.0 ETc) in the main plot, three crop geometry (normal sowing at 50 cm row spacing, paired row sowing at 60 cm x 40 cm and paired row sowing at 30 cm x 70 cm) in the sub-plot and two mulch treatments (no mulch and plastic mulch) in the sub-sub plot and replicated thrice. The fennel variety "RF-101" was used as a test crop, and in the years 2015–16 and 2016-17, it was sown using the *kera* method on the last week of October in varied geometry according to treatment using a seed rate of 10 kg ha^{-1}, and it was collected on the first week of April. In normal sowing at 50 cm spacing; two rows at 50 cm were sown around laterals and 50 cm spacing between two groups of crop rows. In paired row sowing (40 cm × 60 cm); two rows at 40 cm space around laterals and 60 cm spacing between two groups of crop rows, in paired row sowing (30 cm × 70 cm); two rows at 30 cm spacing around laterals and 70 cm spacing between two groups of crop rows. Recommended dose of N-P-K *i.e.*, 90-40-0 kg ha^{-1} was applied through urea (46% N) and DAP (18% N and 46% P_2O_5). Before sowing, the entire amount of phosphorus and 30 kg of nitrogen were administered as a basal dose. The remaining nitrogen was top dressed in two equal portions at 45 DAS and throughout flowering. In order to create a small bund, black polythene sheet (15 micron) was utilized as mulch. It was positioned between rows 20 DAS in ear marked plots. The fennel crop was grown in accordance with the procedures suggested for zone IC. Immediately following sowing, all treatments received a single common irrigation of 25 mm depth for the establishment of the crop.

By modifying the period of water release at a constant flow rate of 4 lit. hr^{-1}, drip irrigation was performed on alternate days at 1.5 kg $ha^{-1}cm^2$ pressure on the basis of crop evapotranspiration (ETc) of 0.4, 0.6, 0.8, and 1.0. The application of drip irrigation was based on ETc levels, or PE * Kp * Kc, with Kc values of 0.70, 0.95, 1.15, and 0.90 for the initial 20 days, the crop development stage, the middle 60 days, and the final stage, respectively.

Where,

ETc - Crop evapotranspiration; PE-Mean pan evaporation from the Class A pan (mm day^{-1}); Kp-Pan evaporation co-efficient; Kc-Crop co-efficient

The total water applied to field was calculated at different ETc levels viz., 0.4, 0.6, 0.8 and 1.0. The quantity of average irrigation water supplied through drip irrigation level of 1.0 ETc was 391.63 mm and rainfall received during cropping period was 14.2 mm. The total water used under the drip irrigation treatment of 1.0 ETc was 430.83 mm. Irrigation events and treatment wise irrigation are presented in Table 1. Based on the seed yield, water consumption efficiency for the growing season was estimated.

$$\text{WUE (kg/ha/mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Water used (mm)}}$$

Relative water content was measured as suggested by (Barrs and Weatherly, 1962). The RWC was determined using the following formula:

$$\text{RWC (\%)} = \frac{\text{(Fresh weight-Dry weight)}}{\text{(Turgid weight-Dry weight)}} \text{ X } 100$$

The experimental data on growth parameters, yield attributes, yield, economics and water use efficiency were statistically analyzed as per the procedure described by Panse and Sukhatme (1985).

Results and discussion

Effect of irrigation levels

Growth, yield attributes and yield: Pooled data of two years, shown in Tables 1 and 2, revealed that increasing irrigation levels up to 0.8 ETc significantly increased growth characters such as plant height, dry matter accumulation plant^{-1}, number of branches plant^{-1} at harvest, and yield parameters such as number of umbels plant^{-1}, number of umbellates umbel^{-1}, number of seeds umbel^{-1}. It was observed that drip irrigation at 1.0 ETc significantly increased plant height (120.0 cm), dry matter accumulation (50.28 g plant^{-1}), the number of primary (6.28) and secondary branches plant^{-1} (9.35) at harvest, the number of umbels plant^{-1} (20.71), the number of umbellates umbel^{-1} (22.44), and the number of seeds umbel^{-1} (222.1), the amount of seed (1714 kg ha^{-1}), the amount of stover (3168 kg ha^{-1}), and the biological yield (4851 kg ha^{-1}) which was at par with 0.8 ETc, but significantly higher than 0.4 and 0.6 ETc. On a pooled basis, seed yield improved by 0.8 ETc over 0.4 and 0.6 ETc irrigation levels, respectively, to the tune of 78.01 and 10.35%. Moreover, the maximum test weight for 1.0 ETc (7.21g) on a pooled basis was equal to that of 0.8 ETc. The maximum harvest index (35.15%) was produced by irrigation at a level of 0.8 ETc, which was comparable to 0.6 and 1.0 ETc in the pooled data. The maintenance of soil moisture at field capacity as well as enhanced rhizosphere owing to larger volume of water may be the causes of the increase in plant height and yield attributes caused by 0.8 and 1.0 ETc irrigation levels using drip irrigation.

As a result, plants take up a lot of moisture and nutrients from the soil, which boosted cell turgidity and elongation and led to better plant growth and development, increasing growth parameters, yield characteristics, and seed production of fennel. The establishment of a water deficit in plant tissue and reduced nutrient availability, which resulted in decreased leaf water content and decreased cell volume and turgor, were the causes for the decrease in plant height at 0.4 and 0.6 ETc irrigation levels. The frequent higher volume water application through drip irrigation that created a favourable microclimate and 0 maintained soil moisture consistently close to field capacity caused the yield increase in drip irrigation with higher ETc levels. Hence, the crop did not experience moisture stress during the growth period. The findings of the current study are closely comparable to those showing that increasing drip irrigation levels from 0.6 to 1.0 ETc improved yield characteristics and fenugreek output (Bhunia et al. 2015).

Table 1. Effect of irrigation levels, crop geometry and mulch on growth and yield attributes of fennel (pooled data of two years)

Treatment	Plant height at harvest (cm)	Dry matter accumulation at harvest (g plant^{-1})	No. of branches plant^{-1} at harvest		Number of umbels plant^{-1}	Number of umbellates umbel^{-1}	Number of seeds umbel^{-1}	Test weight (g)
			Primary	Secondary				
Irrigation levels								
0.4 ETc	109.9	35.54	4.75	5.67	14.33	15.02	183.6	5.54
0.6 ETc	114.2	43.12	5.75	8.01	18.31	19.91	197.3	6.94
0.8 ETc	117.8	48.72	6.08	9.09	20.42	21.93	216.0	7.10
1.0 ETc	120.0	50.28	6.28	9.35	20.71	22.44	222.1	7.21
SEm±	1.04	0.57	0.07	0.09	0.21	0.21	2.36	0.06
CD (P=0.05)	3.14	1.71	0.21	0.29	0.63	0.63	7.15	0.19
Crop geometry								
Normal sowing (50 cm)	114.9	44.32	5.69	8.01	18.26	19.81	204.2	6.73
Paired row sowing (40 cm × 60 cm)	117.4	46.80	5.93	8.28	19.19	20.58	213.0	6.87
Paired row sowing (30 cm × 70 cm)	114.0	42.13	5.53	7.80	17.88	19.09	197.1	6.48
SEm±	0.56	0.49	0.06	0.07	0.15	0.17	1.88	0.05
CD (P=0.05)	1.63	1.40	0.16	0.19	0.44	0.48	5.42	0.16
Mulch								
No mulch	113.7	43.22	5.61	7.93	17.89	19.38	199.8	6.64
Plastic mulch	117.2	45.61	5.82	8.13	18.99	20.27	209.7	6.74
SEm±	0.42	0.36	0.03	0.05	0.11	0.12	1.23	0.04
CD (P=0.05)	1.19	1.01	0.09	0.15	0.31	0.34	3.51	NS

ETc: Crop Evapotranspiration; NS –Non-significant

The findings of this study and those of Meena *et al*. (2016) and Giana *et al*. (2019) are closely related.

Economics: Economic analysis presented in Table 2 revealed that maximum net returns (₹ 104988 ha^{-1}) was recorded with drip irrigation treatment of 1.0 ETc, which was at par with 0.8 ETc (₹ 103149 ha^{-1}). Minimum net returns of ₹41727 ha^{-1} were observed under drip irrigation at 0.4 ETc. Drip irrigation at 0.8 ETc recorded higher net return by ₹ 61422 and 12752 ha^{-1} in pooled basis over 0.4 and 0.6 ETc, respectively. Drip irrigation at 1.0 ETc showed the highest benefit: cost ratio (2.58), which was closely followed by other irrigation levels. Full irrigation is the greatest option for greater net income in maize, according to Kuscu *et al*. (2013), which supports the present study. These findings corroborate the results of Datta and Chatarjee's (2006) in fenugreek and Rao *et al.* (2010) in cumin.

Water use and water use efficiency: Pooled results presented in Table 2 revealed that highest water use of 430.83 mm was recorded with 1.0 ETc and lowest water use of 195.85 mm was recorded in irrigation level of 0.4 ETc on pooled data basis. The average seasonal water use for all the drip treatments at 0.4, 0.6, 0.8 and 1.0 ETc irrigation levels was 195.85, 274.18, 352.50 and 430.83 mm, respectively. Results showed that water use efficiency decreased as irrigation level increased. Higher water use efficiency of 5.48 kg ha^{-1} mm^{-1} was recorded when crop was irrigated at 0.6 ETc. However, crop irrigated at 1.0 ETc irrigation level recorded higher water consumption, lowering its water use efficiency. This may be due to the fact that higher the water supply, higher the evapotranspiration (ET) and ET was proportionally higher than the increase in yield up to certain limit. In general, the trend for the water use efficiency related to the total amount of water use under the different irrigation levels showed that under moderate amount of water consumption, water use efficiency was higher. Besides, moderate irrigation levels reduced deep percolation and increased water extraction from root zone soil. The highest water use efficiency at 0.6 ETc irrigation level might be due to efficient utilization by crop under stress condition for better growth and development of plants. Therefore, the water use efficiency clearly indicates that when water is limiting factor in fennel production, irrigation scheduling should be adjusted to maximize water productivity. Mahajan *et al.* (2007) stated that water use efficiency was almost same at 0.8 and 1.0 ETc, however, it was slightly decreased at 1.2 ETc. Our results are in conformation with the results of Komal *et al.* (2018) in fenugreek.

Relative water content: The pooled data (Table 2), shows that the relative water content was more than 80% at 70 DAS, then abruptly dropped and it was 70-82% at 100 DAS. Nevertheless, the relative water content at 70 and 100 DAS was significantly higher at drip irrigation level of 1.0 ETc, (86.51% and 81.98%, respectively) than 0.4 and 0.6 ETc and was on par with 0.8 ETc.

Table 2. Yield, harvest index, monetary returns, water use (field) and water use efficiency of fennel as influenced by irrigation levels, crop geometry and mulch (pooled data of two years)

.	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Net return (₹ ha^{-1})	B:C ratio	Water use in field (mm)	Water use efficiency (kg ha^{-1} mm^{-1})	Relative water content (%)	
									70 DAS	100 DAS
Irrigation levels										
0.4 ETc	946	2409	3355	28.17	41727	1.08	195.85	4.73	80.53	71.69
0.6 ETc	1526	2931	4457	34.29	90397	2.30	274.18	5.48	84.01	77.97
0.8 ETc	1684	3110	4794	35.15	103149	2.58	352.50	4.84	85.47	81.21
1.0 ETc	1714	3168	4881	35.10	104988	2.58	430.83	4.24	86.51	81.98
SEm±	18	42	50	0.34	1516	-	-	0.05	0.49	0.49
CD (P=0.05)	54	127	153	1.03	4599	-	-	0.16	1.49	1.48
Crop geometry										
Normal sowing (50 cm)	1456	2870	4327	33.08	84124	2.11	313.34	4.73	83.29	76.40
Paired row sowing (40 cm × 60 cm)	1530	3011	4541	33.35	90375	2.27	313.34	4.93	85.03	79.21
Paired row sowing (30 cm × 70 cm)	1416	2831	4247	33.11	80697	2.03	313.34	4.80	84.07	79.02
SEm±	13	30	34	0.29	1135	-	-	0.03	0.41	0.39
CD (P=0.05)	38	85	97	NS	3271	-	-	0.10	1.18	1.14
Mulch										
No mulch	1430	2837	4267	33.08	82413	2.10	313.34	4.60	82.88	76.37
Plastic mulch	1505	2971	4476	33.27	87717	2.17	313.34	5.05	85.38	80.06
SEm±	9.0	19	22	0.20	741	-	-	0.02	0.21	0.27
CD (P=0.05)	25	55	63	NS	2109	-	-	0.06	0.60	0.76

Effect of crop geometry

Growth, yield attributes and yield: Data on pooled mean basis (Table 1) indicated that significantly maximum plant height (117.4 cm), dry matter accumulation (46.80 g plant^{-1}), number of primary branches plant^{-1} (5.93) and secondary branches plant^{-1} at harvest (8.28), number of umbels plant^{-1} (19.19), number of umbellates umbel^{-1} (20.58), number of seeds umbel^{-1} (213.0), seed (1530 kg ha^{-1}), stover (3011 kg ha^{-1}) and biological yield (4541 kg ha^{-1}) were recorded with crop geometry of paired row sowing at 40 cm x 60 cm over normal sowing at 50 cm row spacing and paired row sowing of 30 cm x 70 cm. Paired row sowing of 40 cm x 60 cm, increased the seed yield by 5.08 per cent than normal sown crop at 50 cm row spacing and by 8.05 per cent than paired row sowing at 30 cm x 70 cm. Due to changing crop geometry, the harvest index was unaffected. However, the maximum harvest index was recorded with paired row seeding at 40 cm x 60 cm spacing. Due to proper root system development, good paired row geometry enables satisfactory absorption of nutrients and water from the soil and also helps in efficient interception of solar radiation (Annadurai *et al*., 2009). The higher photosynthetic area (leaf and green stem), higher photosynthetic rate and accumulation of more assimilates boosted the seed yield and quality of output, in paired row (40 cm x 60 cm) crop. These results are in conformity with those of Mehta *et al.* (2013) in ajwain and Kumar *et al*. (2015) in fenugreek.

Economics: Mean data of two years study (Table 2) showed that paired row sowing at 40 cm x 60 cm recorded significantly higher net return of ₹ 90375 ha^{-1} followed by normal sowing at 50 cm row spacing ((₹ 84124 ha^{-1}). However, highest benefit: cost ratio of 2.27 was recorded with paired row sown crop at 40 cm x 60 cm as compared to normal sown crop at 50 cm (2.11) and paired row sowing at 30 cm x 70 cm (2.03). The higher return under this spacing is due to higher seed yield. These results are in conformity with the findings of Dewangan *et al.* (2012).

Water use efficiency: Crop geometry significantly affected water consumption efficiency (Table 2). Nevertheless, paired row sowing at 40 cm x 60 cm and 30 cm x 70 cm were found to have the maximum water use efficiency (4.93 kg ha^{-1} mm^{-1}). The lowest water use efficiency was 4.73 kg ha^{-1} mm^{-1} under normal sowing with 50 cm between rows. Paired-row at 40 cm x 60 cm spacing received more water than those at 30 cm x 70 cm as the plants were closer to drip lines and exposed to more light. Consequently, 40 cm x 60 cm paired row sowing produced the maximum yield, which in turn resulted in the highest water use efficiency. Desai *et al.* (2010) reported similar results in castor.

Relative water content: Paired row sowing with 40 cm x 60 cm row spacing recorded maximum relative water content at 70 and 100 DAS (85.03% and 79.21%, respectively). This was comparable to paired row sowing with a 30 cm x 70 cm row spacing and significantly higher than normal sowing with a 50 cm row spacing on a pooled basis.

Effect of mulch

Growth, yield attributes and yield: A perusal of data in table 1 and 2 indicates that crop grown using plastic mulch registered maximum plant height (117.2 cm), dry matter accumulation (45.61 g plant^{-1}), number of primary branches plant^{-1} (5.82), number of secondary branches plant^{-1} (8.13) at harvest as compared to no mulch treatment. This could be attributed to early and robust plant growth, superior weed control, and improved water use efficiency. Further, results revealed that, on a pooled data basis, the use of plastic mulch produced the highest number of umbels plant^{-1}, umbellates umbel^{-1}, seeds umbel^{-1}, and yield. As comparison to no mulch treatment, plastic mulch increased the number of umbels plant^{-1} by 6.15%, umbellates umbel^{-1} by 4.59%, seeds umbel^{-1} by 4.95%, and seed yield by 5.24%. A similar pattern was seen in the yield of stover. Plastic mulch did not influence the test weight and harvest index of fennel. The superiority of plastic mulch over no mulch could be ascribed to their effectiveness in reducing the evaporation losses by creating the obstacle in external evaporativity by cutting of solar radiation falling on the earth surface and reducing diffusion of water vapour from soil surface into atmosphere. The significant increase in seed and stover yield under plastic mulching was largely a function of better plant growth and physiological activities and consequent increase in yield attributes as mentioned above. This might be due to fact that the polythene mulch has a more pronounced effect on maximum nutrient availability, as well as more availability of soil moisture for longer periods of time, which creates a conducive environment for plant growth and changes the microclimate, whereas in no mulch treatment these parameters are minimal due to higher water loss from the soil surface due to evaporation as well as competition for soil moisture due to increased weed infestation. The results of the current study are comparable to the studies on niger by Saren *et al*. (2008) and on fennel by Yadav and Bhati (2013).

***Economics*:** Application of plastic mulches brought about a significant improvement in net returns and B:C ratio in fennel (Table 2). Maximum net returns was recorded under plastic mulch (₹ 87717 ha^{-1}), which was significantly higher over no mulch treatment and highest B:C ratio (2.17) was recorded in plastic mulch treatment. This may be attributed due to better nutrients uptake and reduction of water losses by evaporation which leads to higher seed yield under this treatment, which directly contributed to net returns. However, plastic mulch produced the higher seed yield and the highest B:C ratio. Mandal and Saren (2012) reported that highest net return was recorded under black polythene mulching in niger.

Water use efficiency: A critical analysis of the data (Table 2) showed that the treatment with plastic mulch had the highest water use efficiency (5.05 kg ha^{-1} mm^{-1}), while the treatment without mulch had the lowest water use efficiency (4.60 kg ha^{-1} mm^{-1}). The improvement in moisture recharge capacity, reduced water loss through evaporation, increased transpiration, and deep percolation, which resulted in an increase in seed yield, were the conditions for the impact of plastic mulching on water use efficiency (Zhang *et al.*, 2005). Yadav and Bhati (2013) reported similar outcomes in fennel.

Interaction of irrigation levels and mulch on water use efficiency

Results (Table 3) revealed that, when combined with plastic mulch, 0.6 ETc considerably increased water use efficiency (5.76 kg ha^{-1} mm^{-1}) as compared to all other treatments. Higher irrigation levels, *i.e.,* 1.0 and 0.8 ETc with significantly more water usage, resulted in a significantly higher yield of fennel, lowering water use efficiency. The benefit of mulch in lowering soil evaporation, increasing plant respiration, and increasing seed yield is shown by the greater water use efficiency of the plastic mulch treatment together with various irrigation levels compared to no mulch. Results indicate that higher crop yield in semi-arid regions may be achieved by proper combination of mulch and irrigation, as also suggested by Huang *et al*. (2005).

Table 3. Interaction of irrigation levels and mulch on water use efficiency (kg ha^{-1} mm^{-1}) of fennel

Mulch	Irrigation levels			
	0.4 ETc	0.6 ETc	0.8 ETc	1.0 ETc
No mulch	4.29	5.21	4.69	4.20
Plastic mulch	5.17	5.76	5.00	4.27
SEm±		0.04		
*CD (P=0.05)		0.12		
SEm±		0.06		
**CD (P=0.05)		0.18		

*CD at 5% for mulch at same level of irrigation

**CD at 5% for irrigation at same level or different level of mulch

Conclusion

The results of the study showed that using plastic mulch instead of no mulch treatment resulted in a higher yield and monetary return in fennel at a drip irrigation level of 0.8 ETc under paired row sowing of 40 cm x 60 cm. Moreover, higher water use efficiency was obtained from plastic mulch treatment with 0.6 ETc drip irrigation treatment. However, drip irrigation with plastic mulch is a good combination for increasing production and effective water use in addition to saving water. Thus, in dry and semi-arid environments, integrated use of drip irrigation and plastic mulch under paired row sowing proved more suitable and lucrative.

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